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BATON ROUGE DEPT OF PHYSICS AND ASTRONOM.. J P WEFEL
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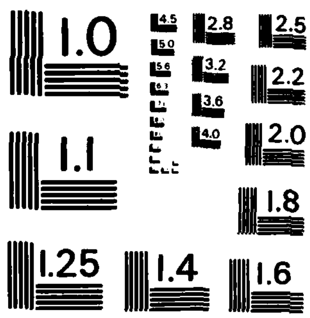


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Annual Report

for

ONR Contract N00014-83-K-0365

"Solar Flares and Magnetospheric Particles:
Investigations Based upon the ONR-602 Experiment"

18 JUL 1984

John P. Wefel
Department of Physics and Astronomy
Louisiana State University
Baton Rouge, LA 70803

I. Introduction:

During the first year of this contract we have initiated the efforts required for the analysis of the data returned from the ONR-602 experiment on the S81-1 mission. This has involved working with the University of Chicago to obtain the experiment data tapes, setting up, at LSU, a processing/analysis system with an unexpected, but required, reformatting of the ONR-602 data tapes, and beginning the scientific analysis of the data. For the latter, we have initiated investigations of the South Atlantic Anomaly region, of the global distribution of low energy magnetospheric particles, and of the time dependence of the low energy particle fluxes. Further, an initial analysis of the mass and charge composition of the solar energic particles observed, over the polar regions, during the mission ~~has been~~ was completed. All of these studies, however, are on-going and will be pursued into the next year of the program.

The overall program described here is a joint venture, with differing areas of concentration, between John Simpson's group at The University of Chicago and our group at LSU. All results developed are to be published jointly by the collaborators.

The remainder of this report will summarize the work performed and the scientific results obtained for the following topics: (a) Data processing/analysis, (b) Solar Energetic Particle composition (c) Global surveys of low energy particle radiation, and (d) The South Atlantic Anomaly region.

II. Data Processing/Analysis:

The ONR-602 data from the S81-1 mission has been subjected to several levels of reduction/processing. First, the raw data from the remote tracking stations was digitized at the Lockheed Palo Alto Research Laboratory and distributed to the experimenters. In the case of ONR-602, this was The University of Chicago. At Chicago the instrument data and ephemeries data were merged, time overlaps and bad readouts were eliminated, calibrations were

applied, and the dataset was sub-divided into two parts: CHART magnetic tapes, containing the ONR-602 instrument rate readouts, and COALT magnetic tapes, containing pulse height analysis data. Copies of both the CHART and COALT tapes, generated on the Chicago Harris computer, were subsequently sent to LSU. The Harris computer is a 3 bytes per word machine, while the LSU analysis is being performed on a DEC-11/23 laboratory data system, a two byte per word machine. This mis-match in word length presented a major difficulty which necessitated unpacking and reformatting the data, sequence by sequence, for use on our machine. Algorithms for this job were developed, tested, and used to reformat the Chicago CHART tapes into a set of LSU CHART tapes usuable for the analysis. The reformatting of the COALT tapes is still in progress. However, the analysis program at LSU involves mainly the CHART data, which has permitted the studies described below to be initiated.

III. Solar Energetic Particle Composition:

The ONR-602 experiment was designed to measure the isotopic and elemental composition of the solar energetic particles, using the ΔE-E technique combined with a new trajectory determining detector system. This flight was the first use in space of this instrument concept, and the apparatus performed quite well.

Figure 1 shows the major solar particle events (flares) occurring during orbital operations of the ONR-602 experiment. The data plotted refer to high energy protons observed outside the magnetsophere by another satellite and reported by NOAA as part of its solar/geophysical data reports. This provides a reference in interplanetary space for the ONR-602 studies. For these flare periods, the ONR-602 instrument was able to study the particle composition during passes over the North and South poles where the geomagnetic cutoff does not affect the particle populations. These polar pass time periods have been through a first phase analysis to determine the charge, mass and energy of each particle that was pulse height analyzed. Figure 2 (top) shows the element distribution obtained for the flare in mid-July, 1982, and figure 2 (bottom) compares the elemental composition of all the flares observed by ONR-602 to several previous studies of solar energtic particles. The overall agreement with previous work is quite good and confirms the deviations from tabulated solar abundances (the bars on the figure) reported previously. Unfortunately, the intensity of these flares was too low to permit significant measurements of the low abundance elements (e.g. Fluorine, Phosphorus, Argon, Calcium, etc.).

Figure 3 shows the preliminary mass histograms of the solar energetic particles for the abundant elements Carbon and Oxygen and for the rarer elements Nitrogen, Neon, Magnesium and Silicon. For the latter four elements, the results are limited by the statistics available, but the ONR-602 data show that the isotopic patterns of these elements do not vary greatly from the patterns found elsewhere in the solar system. This implies that the process of energizing this "sample of the sun" does not involve the mass of the atoms but, probably, only their charge state. No mass fractionation effects are observed for the elements C, N, O, Ne, Mg and Si.

A preliminary report on these results was made to the international scientific community this past summer:

"Isotopic Composition of Solar Flare Accelerated Nuclei: First Results from Phoenix-I", J. A. Simpson, J. P. Wefel and R. Zamow, Proceedings of the 18th International Conference on Cosmic Rays, Bangalore, India, 1983 (in press).

Further work designed to refine the analysis and extend the available energy range is currently in progress.

IV. Global Surveys:

In the low altitude, approximately polar orbit of the S81-1 spacecraft, the ONR-602 instrument has access to the magnetospherically trapped radiation as well as to the interplanetary particles penetrating over the polar regions. To monitor these fluxes, the first two ONR-602 main telescope counting rates , D1$\overline{D2}$ and D1D2$\overline{T1}$, can be employed. In addition, a second, smaller Monitor Telescope is included in the instrumentation to provide measurements at lower energies. Figure 4 shows a schematic diagram of the two telescopes. In the main telescope, the D1$\overline{D2}$ and the D1D2$\overline{T1}$ rates provide information on the higher energy protons, and the scintillator singles rate (SS) is sensitive to the flux of electrons. The Monitor telescope contains a single, thin solid state detector with three discriminator levels, ML, MM and MH, which correspond approximately to low energy protons, alpha particles and $Z>5$ nuclei. Table 1 gives approximate energy ranges corresponding to these rates. Note that for a steep energy spectrum, such as is characteristic of magnetospheric particles or solar flare particles, the counts observed for a specific rate are due mainly to particles at the lower end of the energy ranges.

Using these counting rates, the global distribution of low energy particles has been studied. Figure 5 shows a series of Earth maps on which each point corresponds to a counting rate greater than a specified threshold value. The first plot shows the spacecraft coverage for the period analyzed with white areas signifying a lack of data. Subsequent plots show the distribution for increasing threshold values, giving a spatial view of the integral intensity contours. The results on figure 5 correspond to the SS rate, i.e. medium energy electrons. Note that at the lowest threshold shown, the equatorial regions do not show any counts but the South Atlantic Anomaly region is beginning to emerge. At larger thresholds the polar regions begin to fade leaving the SAA and the "horns" of the Van Allen belts as the brightest regions in medium energy electrons.

Figure 5 can be contrasted with Figure 6 which shows a series of global plots for the low energy proton rate ML. Again, the first panel on the left shows the data coverage (a slightly longer period was employed here) with subsequent panels showing increasing thresholds. For ML the SAA appears at low intensity, but an additional band of low energy protons is observed, approximately tracking the geomagnetic equator. At the highest threshold shown, these features disappear leaving only the polar cap regions and a scattering of background.

This geomagnetic "belt" of low energy protons observed at the low altitude of the S81-1 mission warrants further investigation. It probably represents a charge exchange phenomena whose source is the ring current. The energy of the protons we observe is higher than previous observations, and we must carefully compare the ONR-602 data to other measurements. The plots on figure 6 represent averages over the last two months of the mission, and we must still unfold this data to look for time dependences in this geomagnetic "belt".

Figure 7 shows global plots for several other rates and selected thresholds. Note that the D1 ($D1\overline{D2}$) rate does not show the "belt" structure which implies that the protons in the ML plot have energies below a few MeV, probably near the lower energy of 0.5 MeV. The P3 rate counts the number of events available for pulse height analysis. Note that this plot indicates that there are no PHA events either near the equator or within the SAA. The MM rate, on-the-other-hand, does show a clustering in the vicinity of the SAA, indicating that alpha particles are precipitating in the SAA region.

To summarize the global distribution analysis, we have found (1) a significant low energy proton flux following the geomagnetic equator, (2) the expected electron distribution concentrating in the SAA and the edge of the radiation belts, and (3) important particle distributions in the SAA region. Each of the areas requires further analysis to understand in detail the origin of the observed particle fluxes.

V. The South Atlantic Anomaly:

As described above the SAA provides an interesting region on the Earth for the observation of magnetospheric particles and for monitoring the state of the radiation belts. We have used the flux monitoring capability of ONR-602 to begin an investigation of the SAA region. Figure 5 showed that the SAA can be defined using the SS rate. From this rate, we have located the central region of the SAA extending from about -27° to -47° in geographic latitude and -10° to -55° in longitude. Within this box the spatial distribution and the time dependence of different rates have been investigated.

Figure 8 shows the distribution of counts for the rates SS and D1. (Note that larger latitude, longitude cuts were applied for SS and a high threshold was required for a point.) Figure 9 displays similar data for the MM and MH rates. In all cases the spatial distribution of the observed counts appears to be uniform over the central region of the anomaly. The extra counts for SS in the upper left corner correspond to the edge of the Van Allen belts, as seen in figure 5. An interesting point is the presence of significant numbers of MM and MH counts in the SAA which could imply the presence of both alpha particles and some higher Z nuclei at energies around 1 MeV. The MH threshold is set at an energy deposit of about 10 MeV in a 37 micron thick detector. It does not seem possible for multiple protons to stimulate this high threshold, leading to the tentative conclusion that the MH counts on Figure 9 represent low energy heavy ions trapped in the magnetosphere. It is still necessary to investigate some possible sources of instrument or electronic background before the exact nature and intensity of these MH counts can be determined. Thus, the ONR-602 experiment has observed the signatures of protons, electrons, alphas and, possibly, heavy ions in the SAA region.

Another subject of considerable interest is the time dependence of particle intensities in the magnetosphere. These can be investigated for the type of data on figures 8 and 9. Figure 10 shows three day averages of the SS and ML counting rates restricted only to the SAA passes. The three large spikes in the ML rate may be instrument related and should not be considered significant at this preliminary stage of the analysis. The interesting effect observed on figure 10 is the slow increase in the absolute counting rate over the first half of the mission and an abrupt increase in intensity, with subsequent decay, during the last week of August, 1982. This effect is observed both in the electrons and in the ML proton rate. Figure 11 shows a similar plot for the higher energy protons monitored by the D1 counting rate, and here there appears to be no evident time dependence. Comparison with Figure 1 shows no obvious correlation with the flares observed in interplanetary space. The solar activity, however, was increasing during the first half of the mission, and this might account for some of the increase in the SAA trapped particle intensity.

Current efforts are directed towards trying to understand this time dependence and to correlating the data with other geophysical or solar parameters, such as magnetic storms. It should be noted that the flare in early June of 1982 was reported to be rich in neutrons, and such events may have an effect on magnetospheric particle intensities. The time dependence observed on Figure 10 is a very interesting aspect of the ONR-602 experiment data whose explanation may involve the mechanisms/connections between interplanetary space and the geospace environment.

Table 1

ONR-602 Flux Monitoring Counting Rates

Rate	Main Species	Approximate Energy Interval (MeV)
$D1\overline{D2}$	p	1.7 - 2.8
$D1D2\overline{T1}$	p	2.8 - 3.7
SS	e^-	0.75 - 5
ML	p	0.5 - 9
MM	He	0.8 - 4.5
MH	Z>5	1.1 - 10 (^{12}C)
P3	pulse height analysis rate	

PHOENIX-1 (UNR-602)

SOLAR FLARES DURING S81-1 MISSION

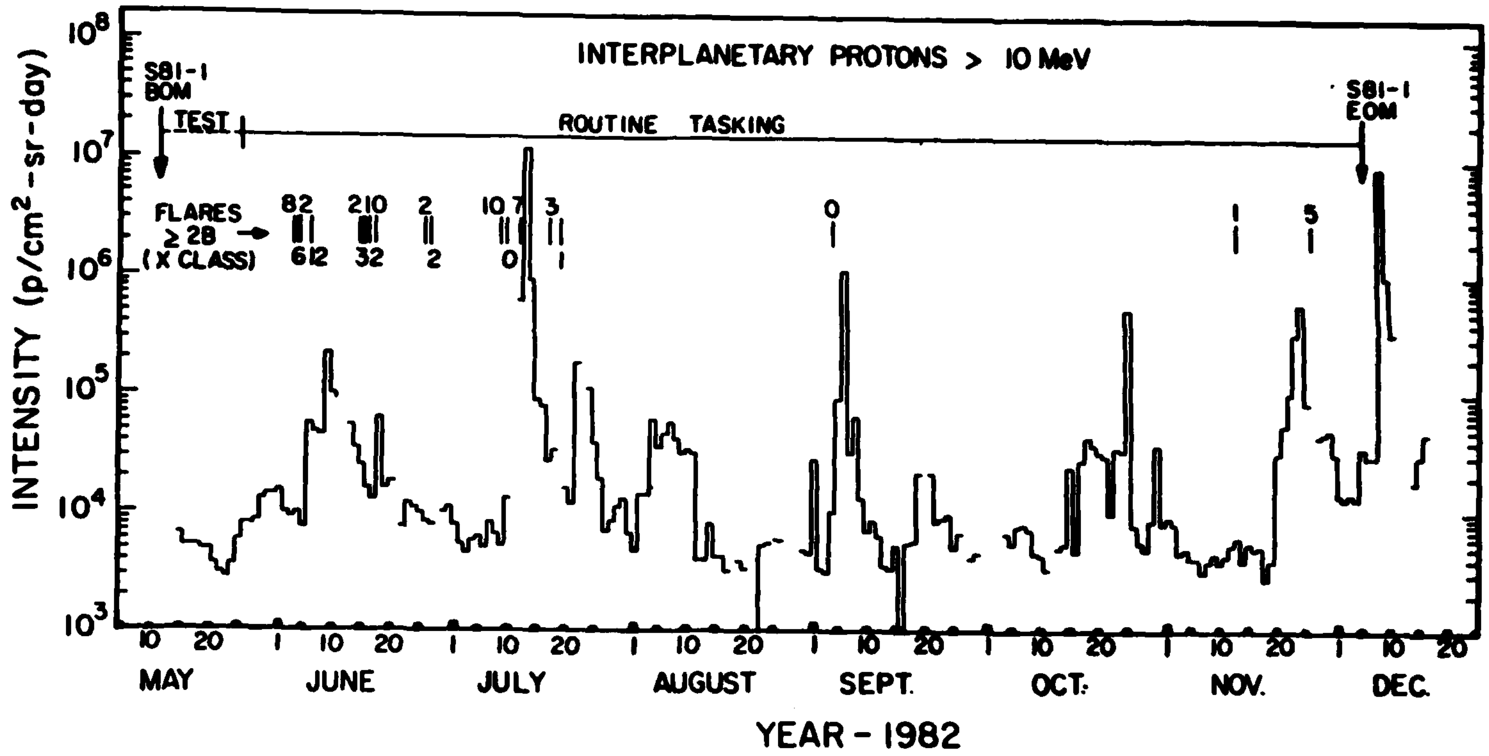


FIGURE 1

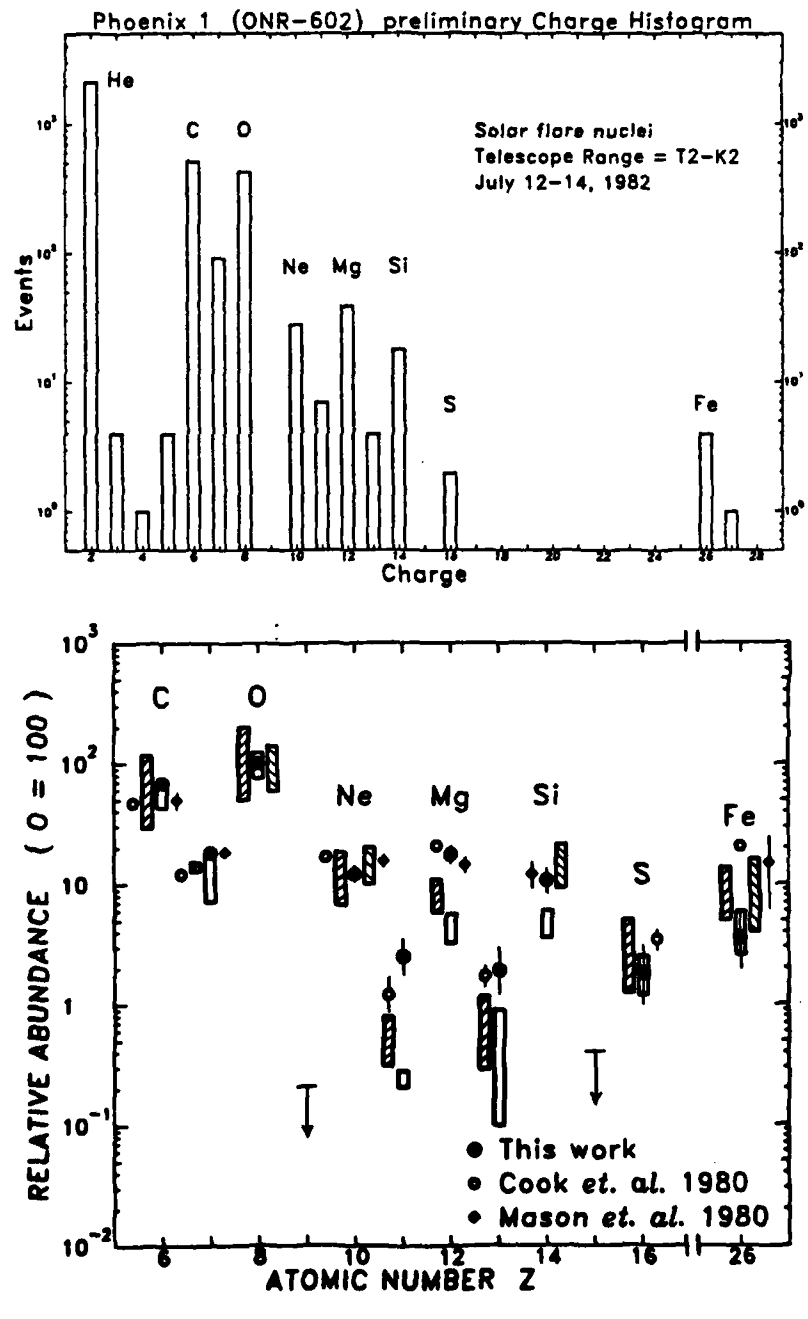

Phoenix 1 (ONR-602) preliminary Charge Histogram
He
C
O
Solar flare nuclei
Telescope Range = T2-K2
July 12-14, 1982
Ne
Mg
Si
S
Fe
Events
Charge
C
O
Ne
Mg
Si
S
Fe
This work
Cook et. al. 1980
Mason et. al. 1980
RELATIVE ABUNDANCE (O = 100)
ATOMIC NUMBER Z

FIGURE 2

SOLAR FLARE ISOTOPE DISTRIBUTIONS

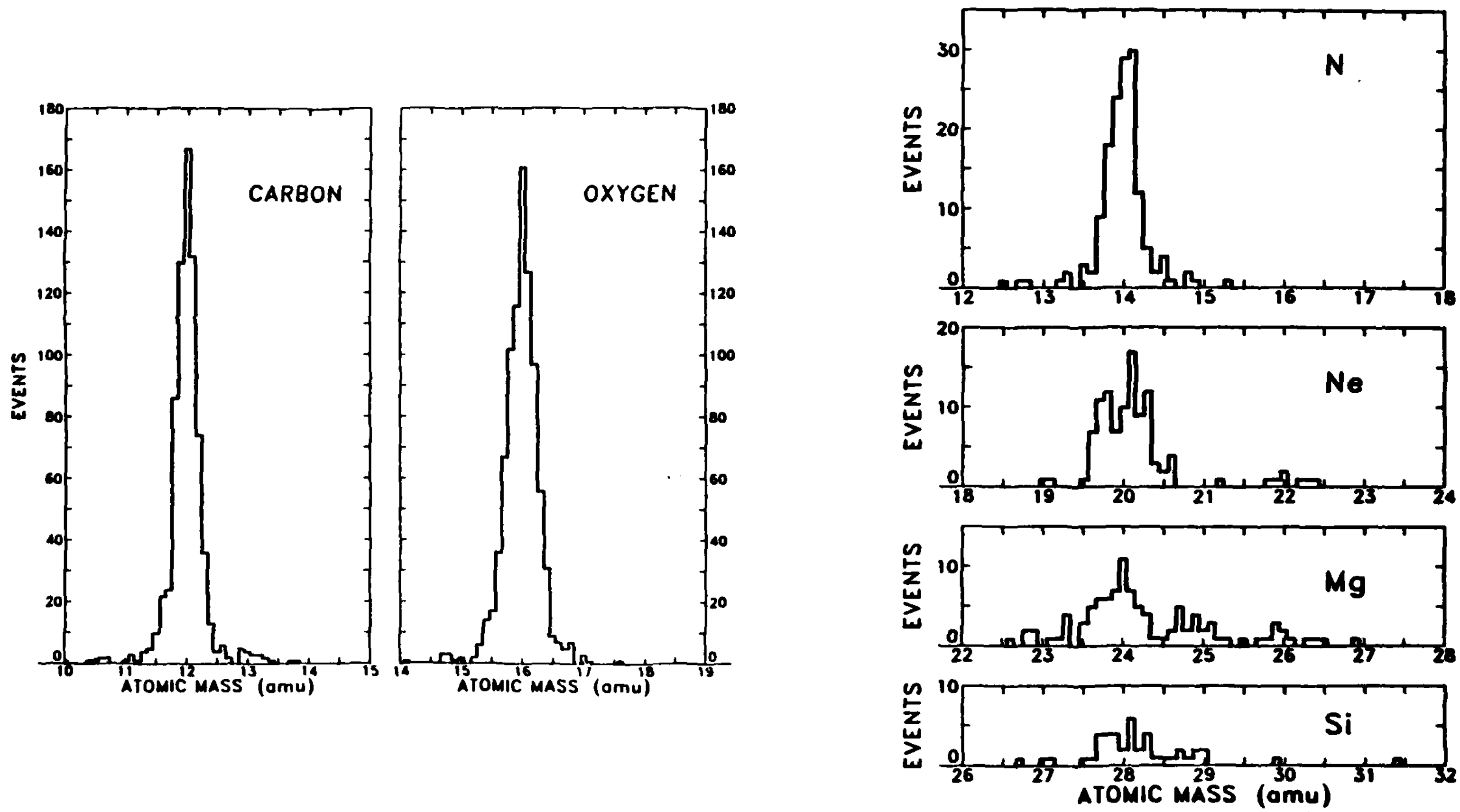


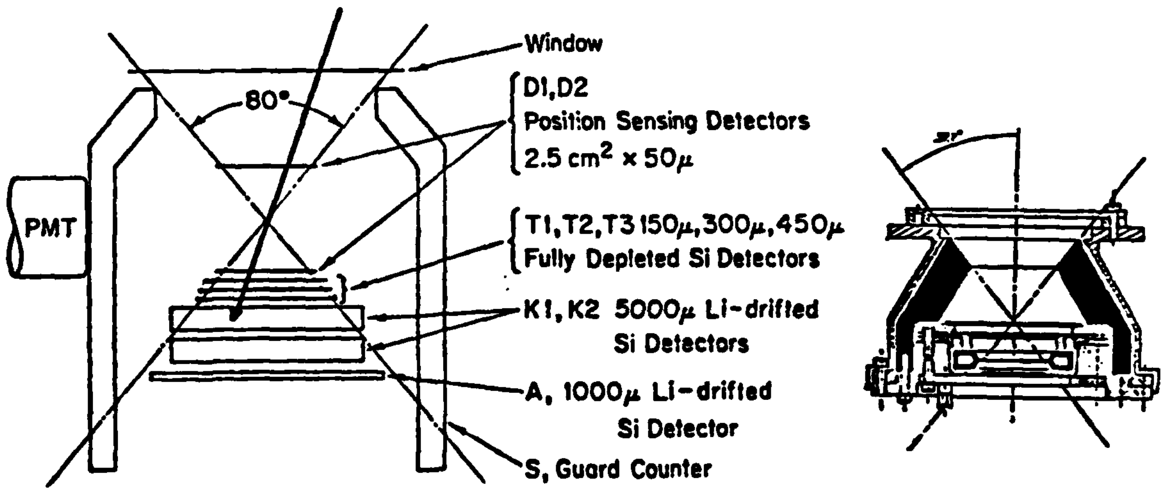
FIGURE 3

PHOENIX 1 (ONR—602)

Telescope Cross Sections

Main Telescope

Monitor



$A\Omega = 1.0\ cm^2$ - sterad

The University of Chicago
January 1977

FIGURE 4

GLOBAL DISTRIBUTION PLOTS

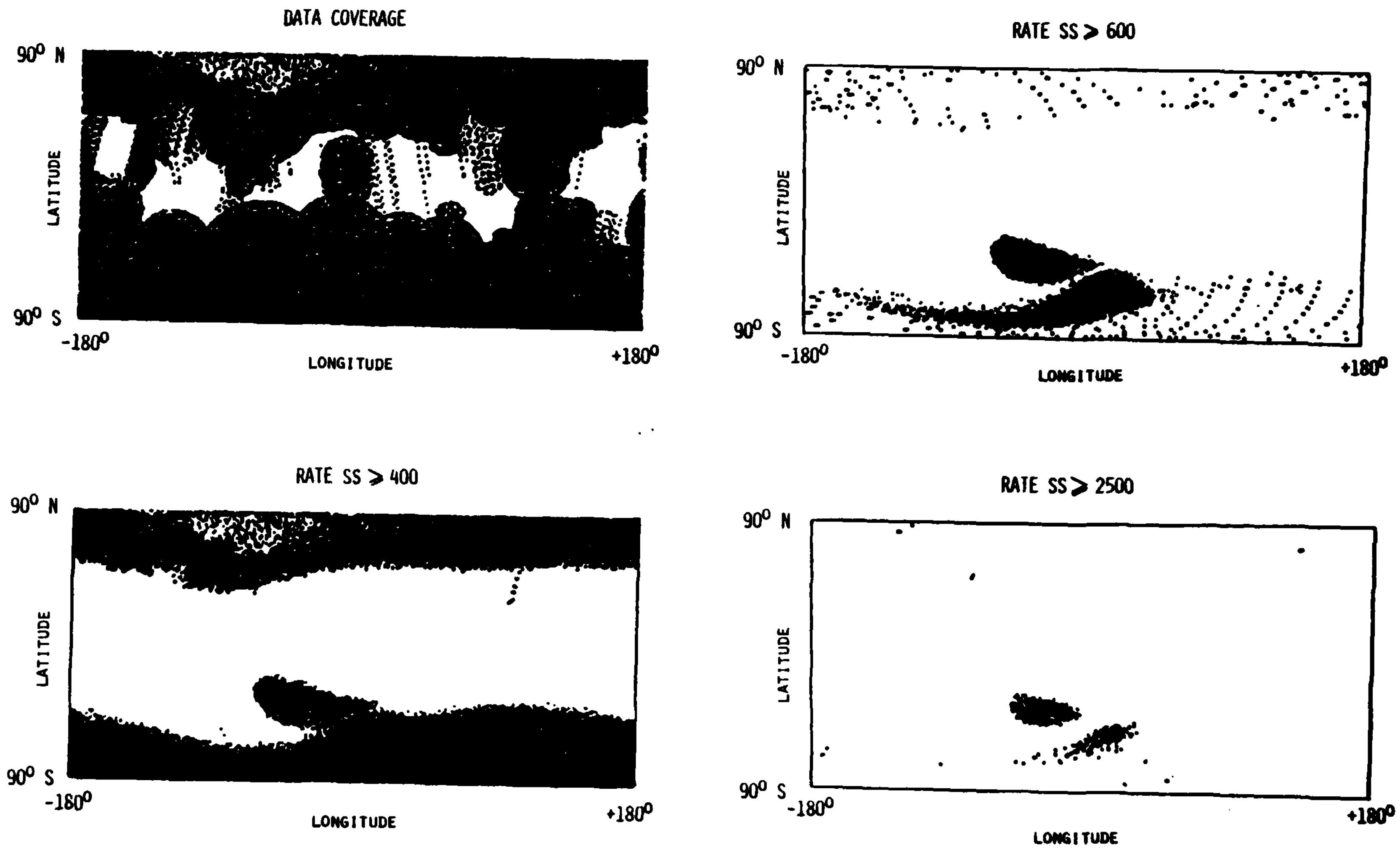


FIGURE 5

GLOBAL DISTRIBUTION PLOTS

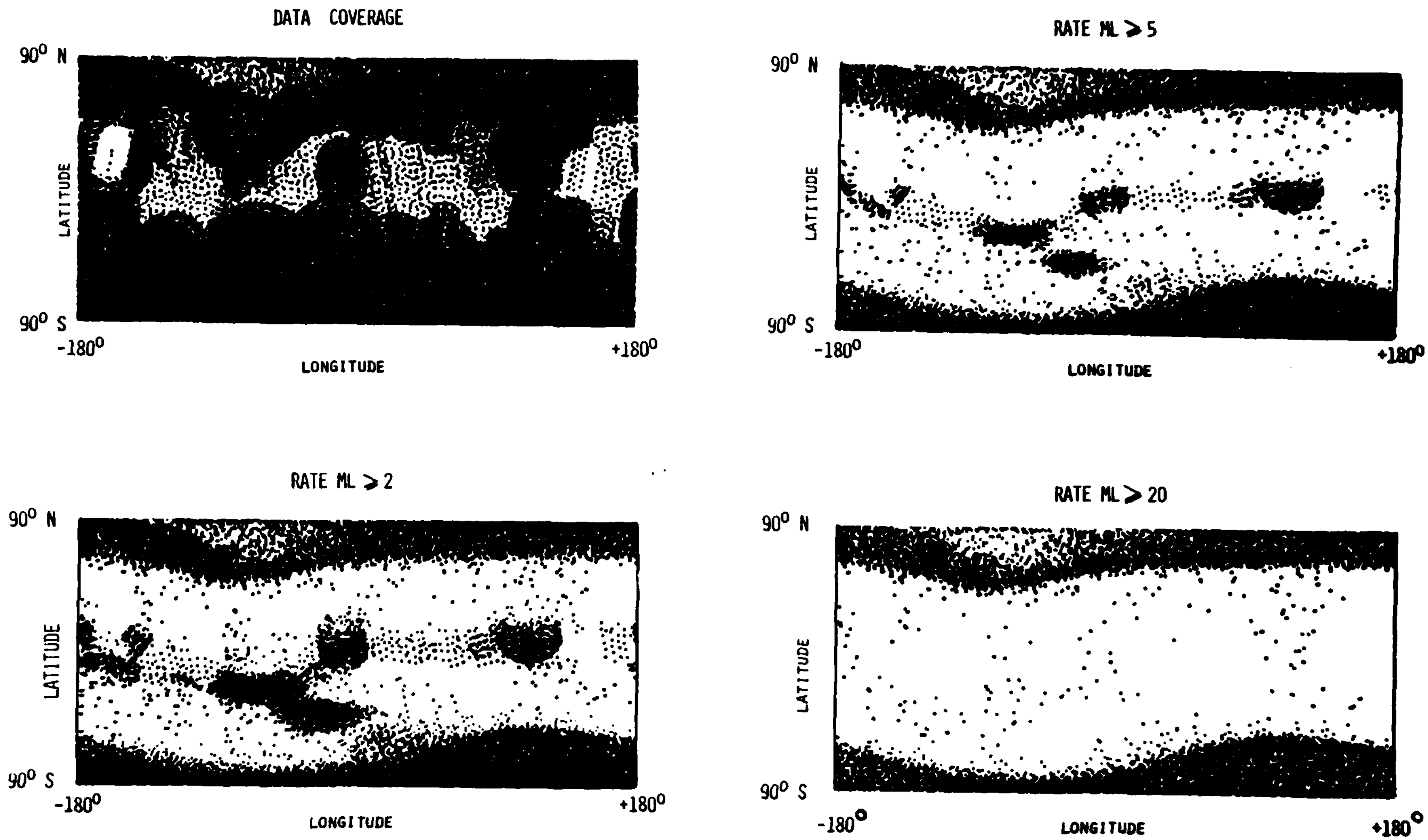


FIGURE 6

GLOBAL DISTRIBUTION PLOTS

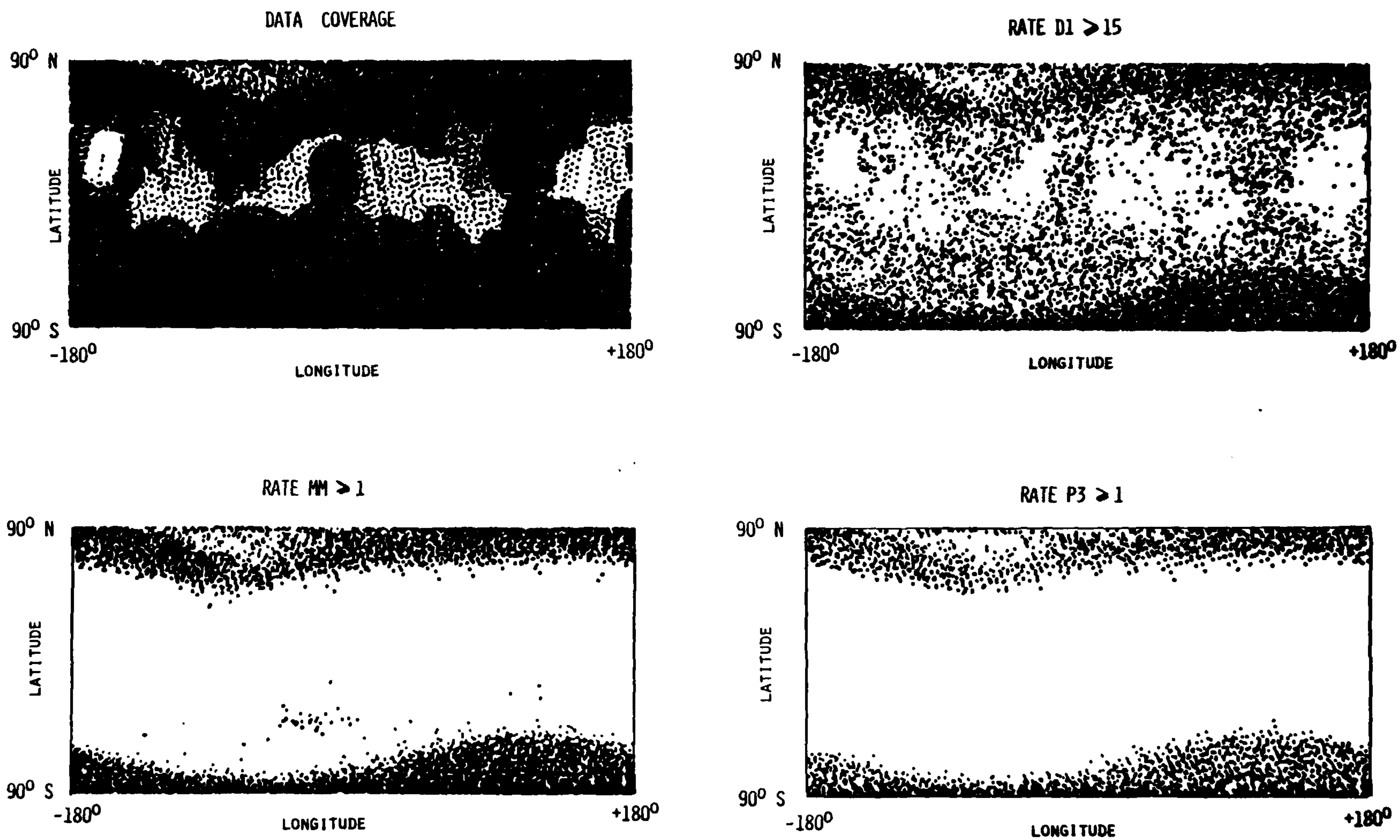


FIGURE 7

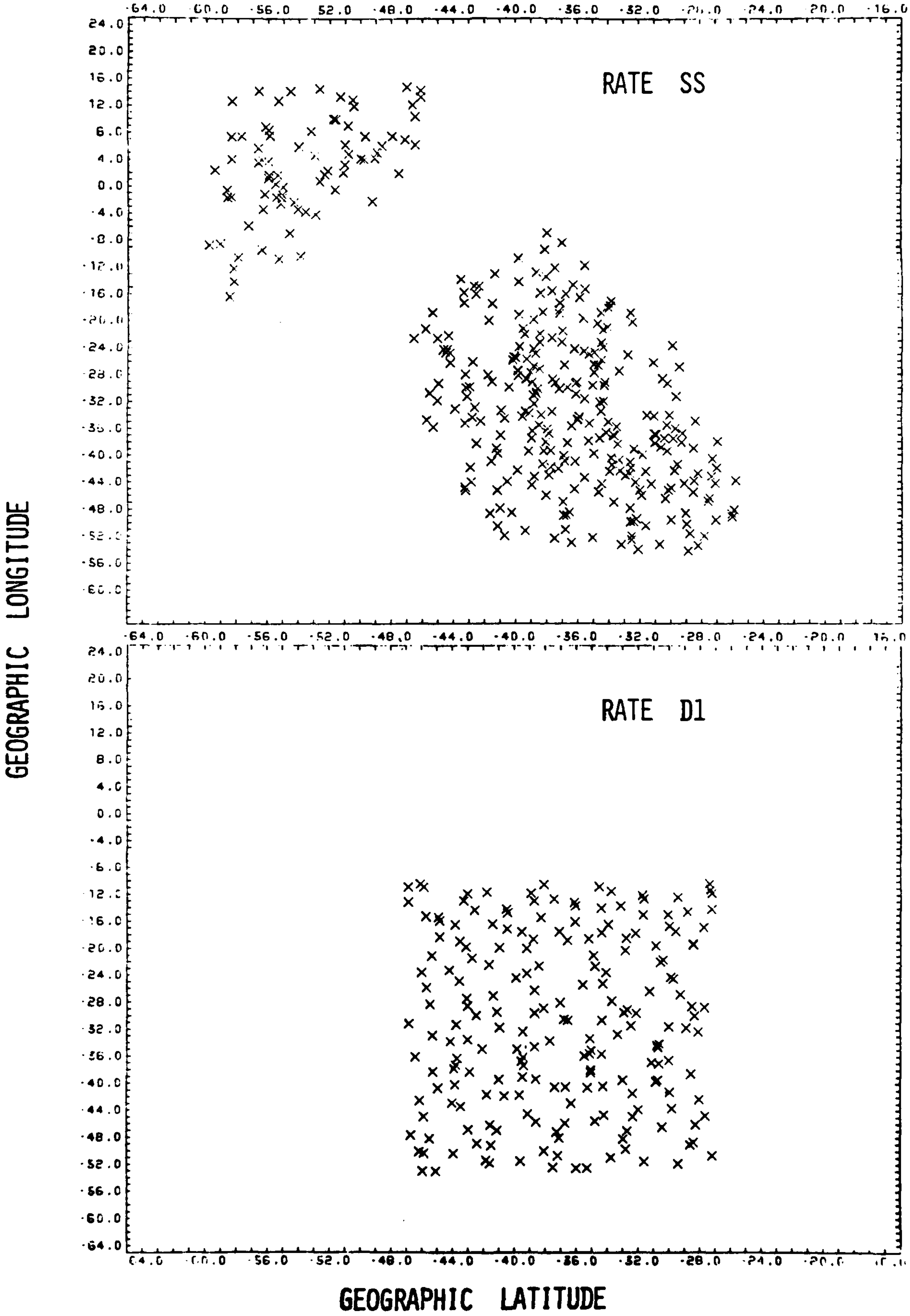


FIGURE 8

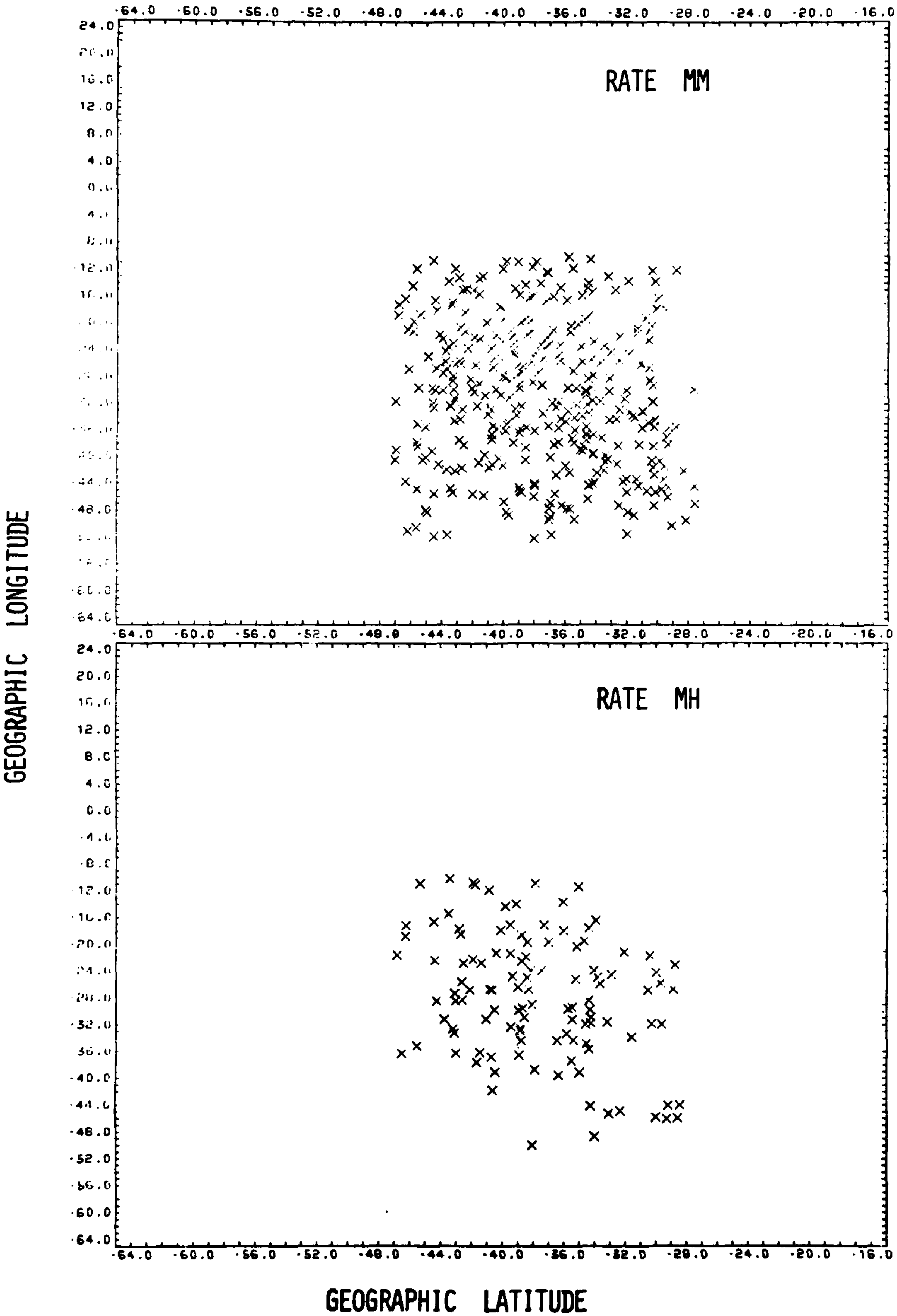
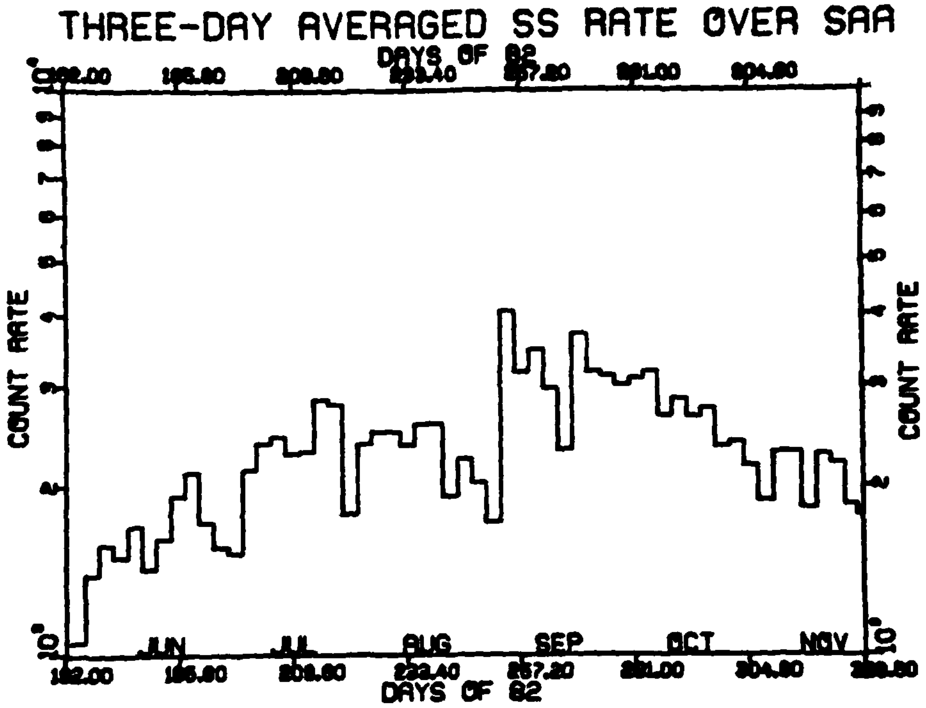

RATE MM
RATE MH
GEOGRAPHIC LONGITUDE
GEOGRAPHIC LATITUDE
-64.0 -60.0 -56.0 -52.0 -48.0 -44.0 -40.0 -36.0 -32.0 -28.0 -24.0 -20.0 -16.0
24.0 20.0 16.0 12.0 8.0 4.0 0.0 -4.0 -8.0 -12.0 -16.0 -20.0 -24.0 -28.0 -32.0 -36.0 -40.0 -44.0 -48.0 -52.0 -56.0 -60.0 -64.0

FIGURE 9


THREE-DAY AVERAGED SS RATE OVER SAA
DAYS OF 82
COUNT RATE
JUN
JUL
AUG
SEP
OCT
NOV
DAYS OF 82

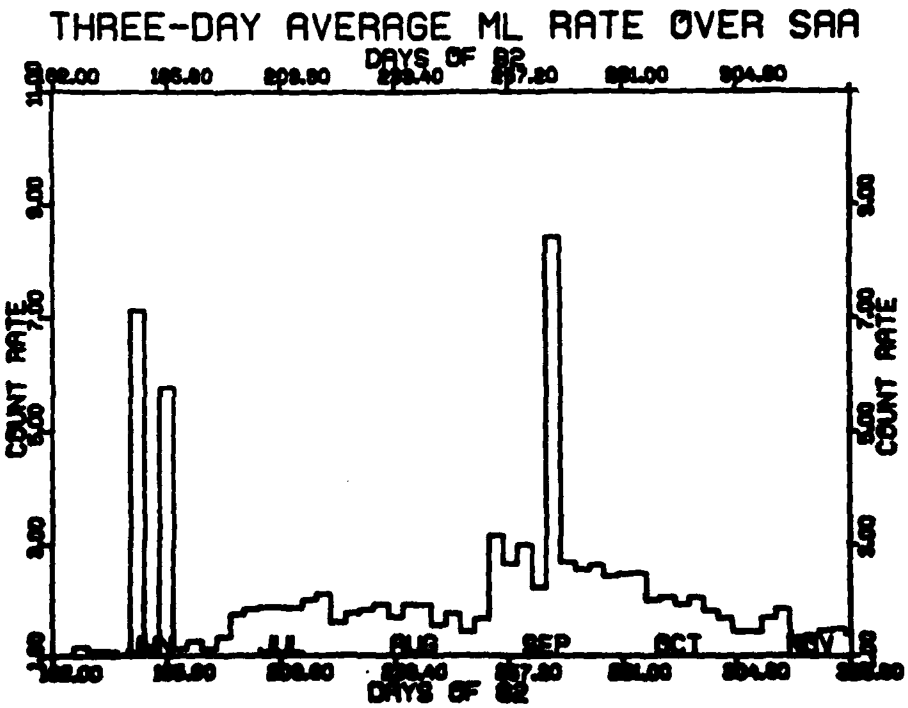

THREE-DAY AVERAGE ML RATE OVER SAA
DAYS OF 82
COUNT RATE
JUL
AUG
SEP
OCT
NOV
DAYS OF 82

FIGURE 10

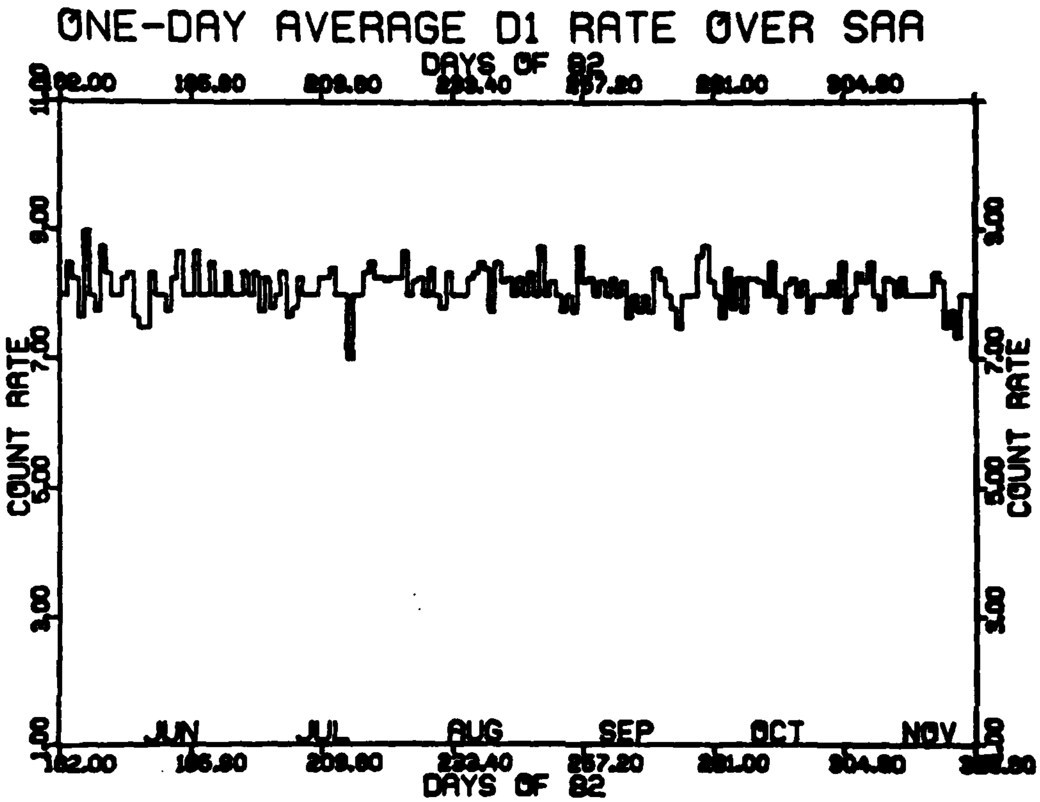

ONE-DAY AVERAGE D1 RATE OVER SAA
DAYS OF 82
COUNT RATE
JUN
JUL
AUG
SEP
OCT
NOV
DAYS OF 82

FIGURE 11

DATE
ILMED
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